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The effects of excess nutrients on tri-trophic food chains in the aquatic ecosystem

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Ecological stoichiometry is an approach that focuses on the balance of energy and elements in environmental interactions, and it leads to new insights and a better understanding of ecological processes and outcomes. Modeling under this framework enables us to investigate the effects of nutrient content (i.e., food quality) on organisms whether the imbalance involves insufficient or excess nutrient content. This phenomenon is called the "stoichiometric knife-edge." In this paper, we develop and analyze a three-trophic-level food chain model that captures this phenomenon. The model tracks two essential elements, carbon, and phosphorus, in each species. We analyze the dynamics of the system such as boundedness and positivity of the solutions, existence and stability conditions of boundary and internal equilibria. Through numerical simulations and bifurcation analyses, we observe the switching of the dynamics of the system between periodic oscillations and chaos. Our findings also show that nutrient-rich food consumption causes (direct or indirect) adverse effects on species.

Keywords— Ecological stoichiometry, stoichiometric knife-edge, tri-tropic food chain model, chaos, maximum Lyapunov exponent